

Lethal and Sublethal Effects of Insecticide Residues on *Orius insidiosus* (Hemiptera: Anthocoridae) and *Geocoris punctipes* (Hemiptera: Lygaeidae)

G. W. ELZEN

Kika de la Garza Subtropical Agricultural Research Center, Beneficial Insects Research Unit, USDA-ARS,
2413 E. Highway 83, Weslaco, TX 78596

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ABSTRACT Laboratory-reared predators, the insidious flower bug, *Orius insidiosus* (Say), and big-eyed bug *Geocoris punctipes* (Say), were exposed to 10 insecticides, including three newer insecticides with novel modes of action, using a residual insecticide bioassay. These species are important predators of several economic pests of cotton. Insecticides tested were: azinphos-methyl, imidacloprid, spinosad, tebufenozide, fipronil, endosulfan, chlorfenapyr, cyfluthrin, profenofos, and malathion. There was considerable variation in response between both species tested to the insecticides. Tebufenozide and cyfluthrin were significantly less toxic to male *O. insidiosus* than malathion. Tebufenozide was also significantly less toxic to female *O. insidiosus* than malathion. Imidacloprid, tebufenozide, and spinosad were significantly less toxic to male *G. punctipes* than chlorfenapyr, endosulfan, and fipronil. Spinosad, tebufenozide, and azinphos-methyl were significantly less toxic to female *G. punctipes* than fipronil and endosulfan. Fecundity of *O. insidiosus* was significantly greater in the spinosad treatment compared with other treatments including the control. Consumption of bollworm, *Helicoverpa zea* (Boddie), eggs by *O. insidiosus* was significantly lower in the fipronil, profenofos, and cyfluthrin treatments compared with other treatments including the control. Consumption of *H. zea* eggs by *G. punctipes* was significantly lower in the malathion, profenofos, endosulfan, fipronil, azinphos-methyl, and imidacloprid treatments compared with the control. Egg consumption by *G. punctipes* was not significantly different in the tebufenozide treatment compared with the control. The lower toxicity of spinosad to *G. punctipes* is consistent with other reports. Based on these results, the following insecticides are not compatible with integrated pest management of cotton pests: malathion, endosulfan, profenofos, fipronil, and cyfluthrin; while imidacloprid, tebufenozide, azinphos-methyl, and spinosad should provide pest control while sparing beneficial species.

KEY WORDS *Orius insidiosus*, *Geocoris punctipes*, insecticide, bioassay

PRIMARY PEST RELEASE and resurgence, and increases in populations of secondary pests, may occur as a result of the selective destruction of beneficial arthropods by chemical pesticides. Even the newly developed biorational pesticides, which are based on natural products, and are more host- or pest-specific, can have profound side effects (Croft 1990). Pest release and resurgence have been widely reported as a consequence of pesticide use or over-use (Michelbacher et al. 1946, Doult 1948, DeBach and Bartlett 1951, Lingren and Ridgway 1967, Flint and van den Bosch 1981).

One of the first definitive studies on the effects of pesticides on beneficial arthropods was reported by DeBach and Bartlett (1951). These authors noted that adverse effects of chemical control treatments on natural enemy populations in citrus were produced in three ways: through direct toxicity, through toxicity or

repellent action of chemical treatments considered inert, and through elimination of beneficial populations by removal of host species.

In addition to direct impact, pesticides often disrupt relationships of associated species in the community, including competitors, hyperparasites, and alternate hosts or prey of natural enemies (Croft 1990). The concept of integrated pest management (IPM) was developed as a consequence of the incompatibility of pesticides and biological control.

Integrated pest management practice in cotton production recommends the preservation of beneficial insects for control of various insect pests. Emphasis on IPM is especially important in early season cotton, when beneficials are capable of maintaining some pests below economic thresholds. Chemical insecticidal sprays become necessary, however, as the growing season progresses and numbers of pest insects increase and plant fruiting structures become more susceptible to attack (Frisbie et al. 1989). Information on the toxicities of various cotton insecticides to several key beneficial species is therefore important in

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Table 1. Toxicity of selected insecticides to *O. insidiosus* and *G. punctipes* adults supplied with insecticide treated *H. zea* eggs for 72 h

Treatment	kg (AI)/ha	% mortality			
		<i>O. insidiosus</i>		<i>G. punctipes</i>	
		Males	Females	Males	Females
Azinphos-methyl	0.28	27.5ab	25.0ab	44.5ab	44.5bc
Imidacloprid	0.052	47.8ab	62.7c	11.1a	50.0bcd
Spinosad	0.099	47.8ab	54.6bc	16.7a	11.1a
Tebufenozide	0.28	21.7a	19.8a	11.1a	16.7ab
Fipronil	0.056	38.8ab	53.9bc	88.9c	94.5d
Endosulfan	1.70	45.8ab	60.0c	77.8c	94.5d
Chlorfenapyr	0.39	57.5bc	31.8abc	61.1bc	66.7cd
Cyfluthrin	0.056	28.4a	43.7abc	44.5ab	22.2ab
Profenofos	0.28	45.4ab	44.3abc	44.5ab	33.3abc
Malathion ULV	1.0	62.5bc	52.8bc	38.9ab	66.7cd
		<i>F</i> = 1.71	<i>F</i> = 1.24	<i>F</i> = 5.11	<i>F</i> = 8.02
		df = 9, 50	df = 9, 50	df = 9, 50	df = 9, 50

Means within a column followed by the same letter are not significantly different ($P \geq 0.05$; LSD [SAS Institute 1988]).

selection of compounds that will minimize mortality of these species.

Several studies have documented the toxic effect of cotton insecticides on beneficials (Plapp and Vinson 1977, Plapp and Bull 1978, Pape and Crowder 1981, Roach and Hopkins 1981, Rajakulendran and Plapp 1982, Butler and Las 1983, Scott et al. 1983, Yokoyama and Pritchard 1984, Yokoyama et al. 1984, Scott et al. 1986, Leggett 1992). The effects of four new compounds at field rates on populations of beneficials: spinosad (Tracer), fipronil (Regent), chlorfenapyr (Pirate), and imidacloprid (Provado) have been tested on beneficial species that inhabit cotton (Peterson et al. 1996, England et al. 1997, Murray and Lloyd 1997, Sparks et al. 1997, Pietrantonio and Benedict 1999).

The insidious flower bug, *Orius insidiosus* (Say), and the big-eyed bug *Geocoris punctipes* (Say) are important predators of several economic pests of cotton (Sterling et al. 1989) that are frequently listed in the above studies. The objective of this study was to provide additional information on the lethal and sublethal effects of selected insecticides on *O. insidiosus* and *G. punctipes*.

Materials and Methods

The *O. insidiosus* and *G. punctipes* cultures were originally collected from cotton near Weslaco, TX, in September 1996. Adults were maintained on green beans as an ovipositional substrate. All colonies were provided bollworm, *Helicoverpa zea* (Boddie), eggs as food and moistened cotton wicks as a water source. Adults were maintained in 14.5 by 2.5-cm ventilated plastic petri dishes, with 40–60 insects per dish. All species were held at $26 \pm 2^\circ\text{C}$, 55–60% RH, and a photoperiod of 14:10 (L:D) h. Adults were less than 1 wk old when tested.

Formulated insecticides tested were fipronil (Regent 2.5 emulsifiable concentrate [EC]; Rhone-Poulenc, Research Triangle Park, NC), spinosad (Tracer 4 suspension concentrate [SC]; Dow Agrosiences, Indianapolis, IN), chlorfenapyr (Pirate 3 [SC]; Amer-

ican Cyanamid, Parsippany, NJ), imidacloprid (Provado 1.6 flowable [F]; Bayer, Kansas City, MO), cyfluthrin (Baythroid 2 [EC]; Bayer), tebufenozide (Confirm 2 [F]; Rohm and Haas, Philadelphia, PA), endosulfan (Phaser 3 [EC]; AgrEvo USA, Wilmington, DE), profenofos (Curacron 8 [EC]; Novartis, Greensboro, NC), azinphos-methyl (Guthion 3 [F]; Bayer), and malathion (Fyfanon 9.79 ultra low volume [ULV]; Cheminova, Wayne, NJ).

Spray Chamber. *Helicoverpa zea* eggs were treated with insecticides using a laboratory spray chamber (DeVries, Hollandale, MN). The sprayer was calibrated to deliver 56 liters/ha using one TXVS-4 nozzle at 1.7 kg/cm² and 4.8 km/h. For ULV application of malathion, the compressed-air system was replaced with a modified ULVA+ spinning disk atomizer head (Dramm, Manitowoc, WI; Elzen et al. 1998). Rates of formulated insecticides applied (see Table 1) were selected by referring to an appropriate control guide (Norman and Sparks 1997) or from manufacturer's recommendations (in the case of nonregistered materials).

Bioassays. *Helicoverpa zea* eggs were treated with insecticides in six replicates using the spray chamber. Eggs were previously frozen at -70°C for 1 h to prevent hatching. Thirty milligrams of eggs was exposed to six male and six female *O. insidiosus* adults (8 d old) in 11-cm-diameter petri dishes per replicate in six replicates. Replicates were supplied with a water-moistened cotton wick and one green bean (6 cm long). Six 4-cm gauze-faced pads were spread apart exposing both inner surfaces. Both inner pieces were placed in the petri dishes as oviposition substrates. The number of eggs on each surface was counted every 24 h for a total time of 72 h. Mortality, milligrams of eggs consumed, and number of eggs laid (fecundity) were determined at 72 h posttreatment. Egg consumption was expressed as a percentage of the original amount of eggs supplied. This bioassay was repeated for the parameters of mortality and mg of eggs consumed for *G. punctipes*.

Insects were held at $26 \pm 2^\circ\text{C}$, 55–60% RH, and a photoperiod of 14:10 (L:D) h. Mortality was deter-

mined by failure of insects to move when prodded by a probe. Control mortality was never >10.0%; data were corrected for control mortality using Abbott's (1925) formula before analyses. Percentage data were arcsine transformed and analyzed by analysis of variance. Means were separated by least significant difference (LSD, $P \leq 0.05$ [SAS Institute 1988]); actual means are shown in all tables.

Results and Discussion

Insecticide toxicity among treatments to male *O. insidiosus* ranged from a low of 21.7% (tebufenozide) to a high of 62.5% (malathion) (Table 1). Tebufenozide and cyfluthrin were significantly less toxic to males than malathion. Toxicity of the insecticides to female *O. insidiosus* ranged from a low of 19.8% (tebufenozide) to a high of 62.7% (imidacloprid). Tebufenozide was also significantly less toxic than malathion to females.

For *G. punctipes* males, imidacloprid, tebufenozide, and spinosad were significantly less toxic than chlorfenapyr, endosulfan, and fipronil (Table 1). Spinosad, tebufenozide, and azinphos-methyl were significantly less toxic to female *G. punctipes* than fipronil and endosulfan.

Elzen et al. (1998) tested *O. insidiosus* and *G. punctipes* adults in a foliar residual bioassay using the same rates as herein. They found no mortality of *G. punctipes* in treatments with spinosad, endosulfan, cyfluthrin, and profenofos. This is in contrast to the mortalities found in the current results (Table 1). However, mortalities with fipronil, chlorfenapyr, and malathion were similar in their study to the results shown here (Table 1). Most of the treatments in Elzen et al. (1998) produced similar mortality in *O. insidiosus* as those presented here; however, azinphos-methyl, imidacloprid, and spinosad treatments produced much lower mortality than those shown here (Table 1). This provides support for the rationale of multiple testing methods for insecticides to evaluate various effects (Banken and Stark 1998). Some of the chemicals tested in the earlier study appeared harmless to the beneficials, but upon feeding treated eggs to these insects, more deleterious effects were found.

Pietrantonio and Benedict (1999) rated chlorfenapyr as slightly harmful (causing 25–50% mortality) to *O. insidiosus*. They also reported that spinosad was harmless (causing < 25% mortality) to *O. insidiosus*. We found similar mortality to *O. insidiosus* exposed to chlorfenapyr; however, spinosad produced much higher mortality in *O. insidiosus* in our tests (Table 1). Schoonover and Larson (1995) reported that spinosad was 450-fold less toxic to *O. insidiosus* than cypermethrin. England et al. (1997) found 76% mortality in *O. insidiosus* exposed to endosulfan treated cotton leaves (0.57 kg[AI]/ha) 24 h after exposure; we observed lower mortality to endosulfan (1.7 kg[AI]/ha) 72 h after exposure. They also reported that malathion ULV caused 100% mortality; at the same rates we observed lower mortality with malathion (Table 1).

Table 2. Effect of selected insecticides on *O. insidiosus* adults supplied with insecticide treated *H. zea* eggs for 72 h

Treatment	Kg (AI)/ha	Eggs/female \pm SE	
		Fecundity	% <i>H. zea</i> consumption
Spinosad	0.099	58.7 \pm 9.1d	30.6 \pm 4.2cd
Tebufenozide	0.28	33.0 \pm 8.5c	40.1 \pm 9.4d
Imidacloprid	0.052	31.5 \pm 5.3c	29.6 \pm 4.1cd
Azinphos-methyl	0.28	28.7 \pm 9.3c	27.8 \pm 3.2cd
Chlorfenapyr	0.39	23.8 \pm 4.2c	31.0 \pm 2.0cd
Endosulfan	1.70	23.5 \pm 3.2bc	23.5 \pm 1.0bc
Malathion ULV	1.00	10.3 \pm 4.6ab	23.0 \pm 2.4bc
Cyfluthrin	0.056	7.2 \pm 3.0ab	13.6 \pm 1.2ab
Profenofos	0.28	4.3 \pm 2.0a	13.3 \pm 1.1ab
Fipronil	0.056	0.3 \pm 0.2a	11.3 \pm 2.2a
Control	—	30.8 \pm 6.4c	27.3 \pm 4.5c
		$F = 6.96$	$F = 4.75$
		df = 10, 55	df = 10, 55

Means within a column followed by the same letter are not significantly different ($P \geq 0.05$; LSD [SAS Institute 1988]).

Tillman and Mulrooney (1997) reported higher mortality in *G. punctipes* treated with the same rate of ULV malathion as in our study, but they reported similar mortality with the same rate of fipronil (although applied ULV). Mizell and Sconyers (1992) observed 77.6% mortality to *G. punctipes* exposed to 127.4 ppm of imidacloprid; we also found high mortality in most cases (Table 1). Their method was based upon dipping plastic petri dishes or diet cups with lids into pesticide solutions; thus, the entire arena would have been coated with insecticide, whereas in our tests, only *H. zea* eggs were exposed to insecticide and these were fed upon by test insects.

Fecundity of *O. insidiosus* was significantly greater in the spinosad treatment compared with other treatments including the control. Fecundity in treatments with fipronil, profenofos, cyfluthrin, and malathion was significantly lower compared with the control (Table 2). Consumption of *H. zea* eggs by *O. insidiosus* was significantly lower in the fipronil, profenofos, and cyfluthrin treatments compared with other treatments including the control. Consumption of *H. zea* eggs by *G. punctipes* was significantly lower in the malathion, profenofos, endosulfan, fipronil, azinphos-methyl, and imidacloprid treatments compared with the control. Egg consumption was not significantly different in the tebufenozide treatment compared with the control (Table 3).

There was considerable variability in response of the two species tested to the insecticides selected. However, the lower toxicity of spinosad to *G. punctipes* we observed is consistent with the study of Murray and Lloyd (1997) who reported that spinosad was not disruptive to predator populations in Australian cotton and suggested that the product has an important role in integrated management programs. Further, Hendrix et al. (1997) reported that spinosad was softer on beneficials than chlorfenapyr, deltamethrin (Decis), *lambda*-cyhalothrin (Karate), or acephate (Orthene), and Pietrantonio and Benedict (1999) rated spinosad as harmless (causing <25% mortality) to *Cotesia plutellae* (Kurdjumov) in laboratory studies.

Table 3. Effect of selected insecticides on *G. punctipes* adults supplied with insecticide treated *H. zea* eggs for 72 h

Treatment	Kg (AI)/ha	% <i>H. zea</i> eggs consumed/ female \pm SE
Tebufenozide	0.28	66.3 \pm 7.5d
Spinosad	0.099	54.4 \pm 11.9cd
Chlorfenapyr	0.39	51.8 \pm 3.5cd
Cyfluthrin	0.056	40.4 \pm 8.2bcd
Imidacloprid	0.052	35.0 \pm 10.7abc
Azinphos-methyl	0.28	31.7 \pm 10.4abc
Fipronil	0.056	27.7 \pm 8.4ab
Endosulfan	1.70	25.4 \pm 9.8ab
Profenofos	0.28	24.8 \pm 3.6ab
Malathion ULV	1.00	11.0 \pm 6.2a
Control	—	66.3 \pm 7.5d
		F = 2.49
		df = 10, 55

Means followed by the same letter are not significantly different ($P \geq 0.05$; LSD [SAS Institute 1988]).

Cotton IPM is highly complex and relies on many factors, including the selectivity of pesticides. Data on the selectivity of newer insecticides with novel modes of action are useful, because these may replace conventional insecticides. While most insecticides are very toxic to beneficials (or equally toxic to pests and beneficials), IPM seeks to employ insecticides which are less toxic to beneficial insects. Further studies are necessary to determine the comparative toxicity of selected insecticides to pest species versus key beneficial organisms.

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